DIELECTRIC IMAGING FOR LOCALISATION AND DETECTION OF BREAST TUMOURS

Alan W Preece, Reg H Johnson, Josephine L Green, Martin P Robinson

Department of Medical Physics and Bioengineering, Bristol Oncology Centre,
United Bristol Healthcare NHS Trust, BRISTOL BS2 8ED, UK

Abstract A new type of resonant dielectric sensor has been developed, which is non-invasive but has adequate depth sensitivity for the detection of tumours. In measurement ε' and ε" are estimated from the changes in resonant frequency and Q factor respectively. A clinical measurement system has been tested on a breast tumour equivalent phantom and on patients and controls and has been shown to be capable of demonstrating the presence of a tumour.

Introduction Mammography and ultrasound are basic tools for detecting breast tumours, using the corresponding changes in electron density or acoustic impedance. Associated with tumour growth is an increase in cellularity and an increase in blood supply (angiogenesis) which results in an increased water content, shown by measurements of tissue samples in a resonant cavity (1). In the breast, this may lead to a differential value of permittivity which can be detected externally. Measurements on live tissue confirm that, at least in post-menopausal women, it may be possible to detect the presence of a tumour (2). This study seeks to evaluate the possibilities and problems of using a UHF microwave sensor to make measurements on a breast tumour phantom and patients.
The open ended coaxial line (3) can be used to determine the impedance (and thus the permittivity) when applied to an unknown dielectric by means of the change in phase and amplitude of the reflected signal registered by a vector network analyser. A resonant version (4) can perform the same measurements at a single frequency using return loss and short circuit length to measure conductance and reactance respectively. The aperture is effectively the gap between the inner and outer conductors, so that for a 14mm line the field lines at the open end fringe into the tissue by only a few millimetres and any measurement is dominated by the skin.
To overcome this limitation, a new type of sensor with a larger aperture, and greater field penetration, has been designed to operate on the same principle as the resonant device.

Technique The new sensor is a resonant inductance-capacitance circuit (Fig. 1) (International Patent Application No. PCT/GB92/01160) which is matched to a 50ohm line by a coupling capacitance and consists of a single rectangular turn of flat conducting sheet having a 25mm square radiating part facing the tissue to be measured through an aperture in a screening can (Fig. 2). A variable capacitor remote from the radiating face enables the device to resonate at 500MHz in air and the coupling is adjusted to give minimum return loss (typically greater than 40dB). Standard liquids (5) with known complex permittivity are used to calibrate the sensor, which is spaced from the liquid or tissue by a thin window.

For tumour detection, the device is first adjusted in air and then applied to the surface of the breast over a previously marked grid. The change in resonant frequency (ΔF) and Q-factor are recorded, typically after 10 averages. At present the two parameters (Δf and Δ1/Q) which are independently affected by ε' and ε" are plotted on a grid with interpolation.

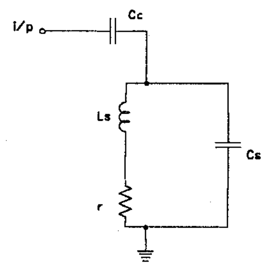

Fig.1 Simple equivalent circuit of sensor

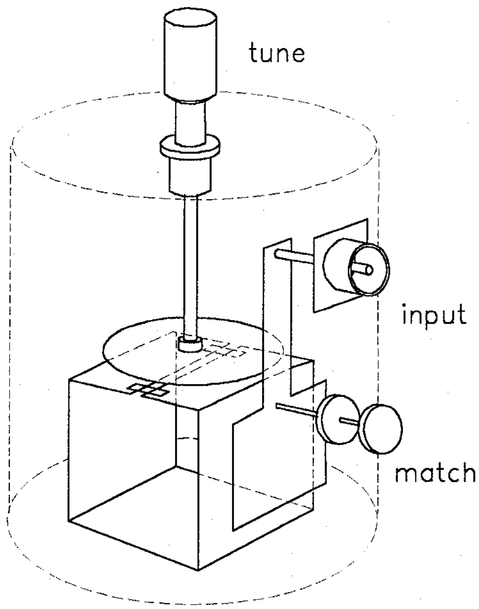

Fig.2 Outline of sensor construction.

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Measurements

A) In liquids: When placed in contact with liquids of known dielectric constant the resonant frequency relative to air is decreased. Particularly with low loss materials the volume of liquid must be large enough to give insignificant reflections from the container wall. Fig. 3 shows Δf as function of ε' for a number of liquids, together with the Δ(100/Q) as a function of ε".

At much higher values of ε' and ε" these relationships are not valid; as for example in high salt concentrations in water. Therefore the simple equivalent circuit in Fig. 1 is inadequate to describe the behaviour of the device. However the tissue permittivity values for tumour and normal tissue fall inside the usable range of the sensor.

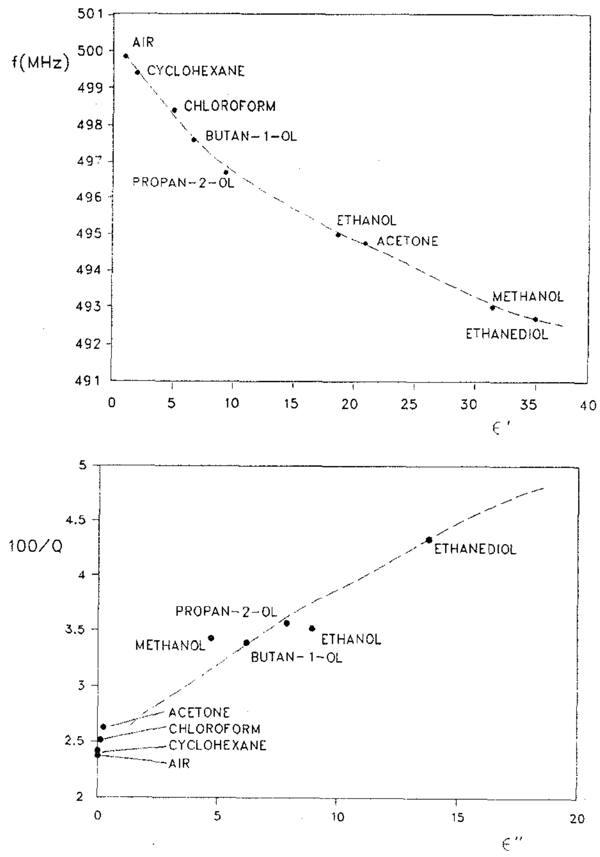

Fig.3 Relationship between ε' and Δf, and ε" and 100/Q respectively for standard liquids.

B) Of field penetration: Three methods have been used to determine the field pattern and effective penetration. These have been in close agreement and are fully documented elsewhere in this issue (6). For liquids of value ε' = 10, and ε" = 1.8, at 500MHz, this is effectively 3cm (e^{-1} field) and would be close to that expected for normal breast tissue.

C) Of tissue equivalent materials: The simple tumour model consists of a cylinder of muscle equivalent material in a matrix of normal tissue equivalent material (7). This has been used to test the sensor. The results of a simple scan are shown in Fig. 4 using an interpolation technique (courtesy of J Duchene, Compiegne.)

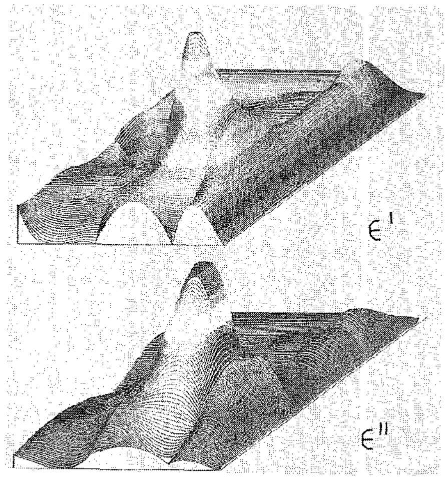

Fig.4 Interpolated reconstruction of a scan of a breast tumour phantom.

D) In clinical subjects: To date 25 patients have been 'scanned' and the results show that symmetrical and uniform results are obtained for healthy volunteers, except for an image of the nipple. In younger patients with cysts no discontinuities have been detected, but established tumours in the older patient can readily be visualised., especially when the mirror images of left and right are superimposed.

Conclusions The new non-invasive dielectric sensor can detect breast tumours. Further work is required to determine the sensor design which achieves optimum resolution and adequate field penetration. The measurement is harmless, simple and in practice takes less than ten minutes per scan.

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